Development of Commodity-Driven Vessel Movements for Economic Analysis of Port Improvements

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CORPS OF ENGINEERS

Cost Justification Required For Projects

- Benefit-Cost Analysis
  - Without Project costs and benefits
  - With Project costs and benefits
  - Life Cycle Analysis
    - 50 years into the future
    - Implies forecasting
  - Risk and Uncertainty
- IWR Develops Tools For Planning In This Context
  - Basic Data Development
  - Data Analysis and Visualization Tools
  - Monte Carlo Simulation Models
  - Multiple Criterion Decision Aids
  - Cost Effectiveness Analysis

Deep-Draft Navigation Tools

- Evolving set of statistical, forecasting, and simulation tools for analysis of vessel movement in harbors
  - Planning Level, not Operational
- Simulate impacts of alternative harbor improvements:
  - Potential reductions in vessel delays
  - Potential increases in loading, vessel capacity
- Develop and analyze forecasts of future fleet movements, based on commodity forecasts
- Analyze existing vessel movements

Navigation Planning Tool Suite

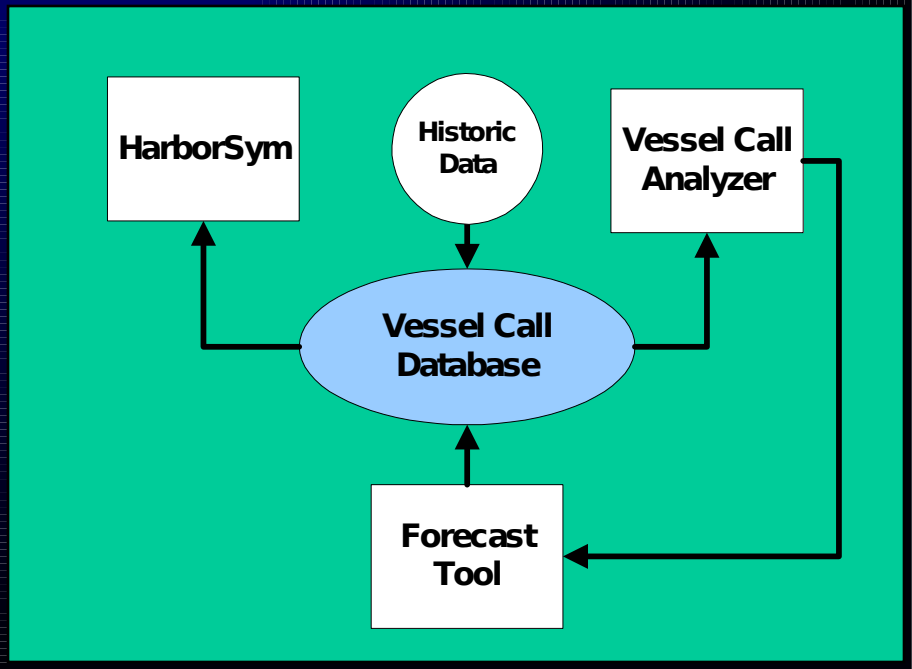
- HarborSym Monte Carlo Port Simulation
- Vessel Call Database
- Vessel Call Analyzer
- Commodity-Driven Forecast Tool

Microsoft Access Data Base

C++ Computational Kernels

R Statistical Software

Graphical User Interface

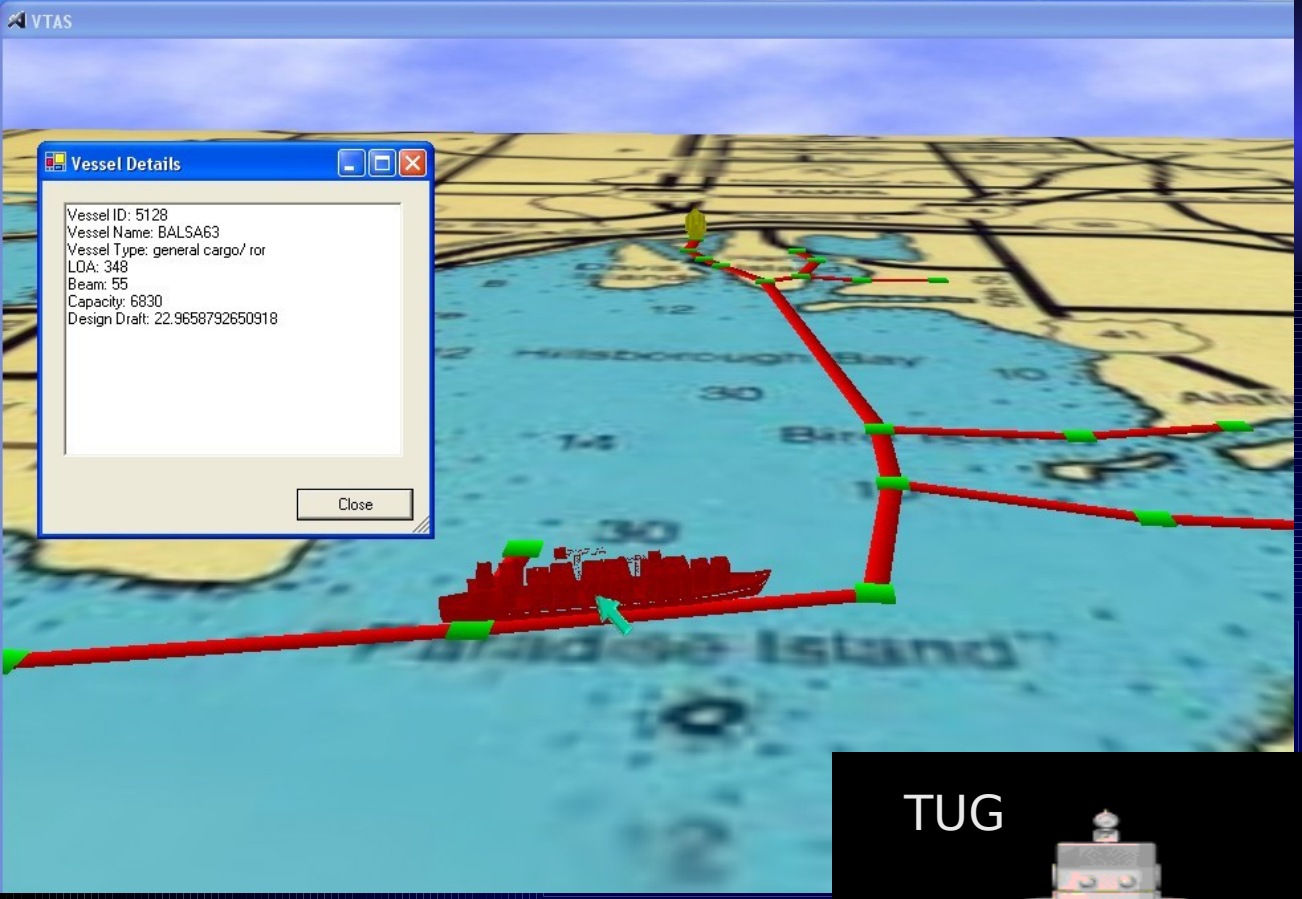


Transparency

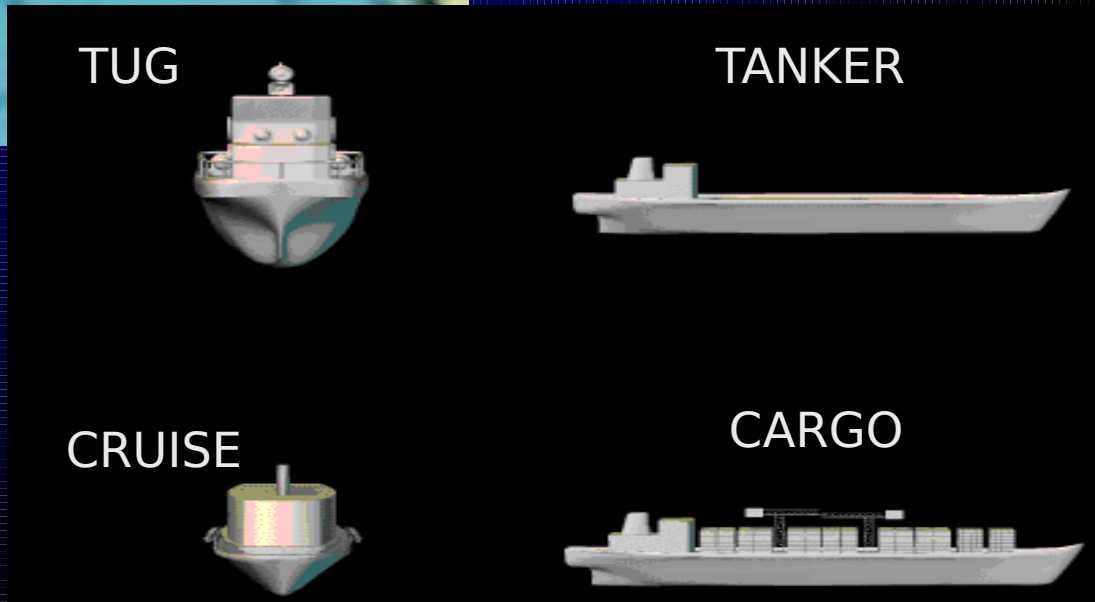
Non-Proprietary Tools

HarborSym

- Planning-Level Model
  - Single Port
  - Focus on water-side, not land-side
- Data-Driven
  - Port layout
  - Vessel Calls
  - Speeds
  - Transit Rules
- Vessel movements / interactions within harbor
- Outputs
  - Times in system (travel, docking, etc.)
  - Delay times



HarborSym Monte Carlo Simulation Model



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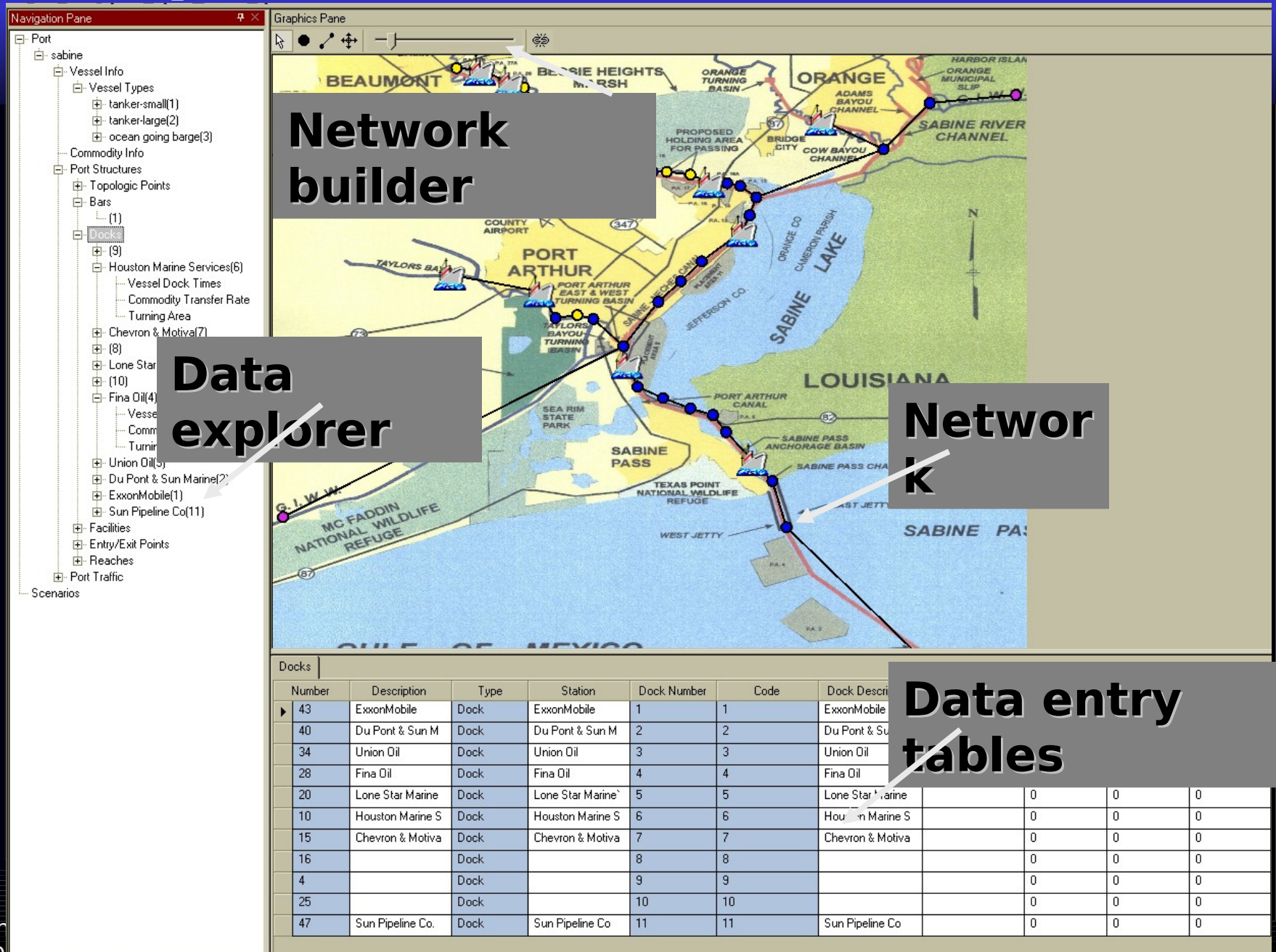
Graphical User Interface



Number	Description	Type	Station	Dock Number	Code	Dock Descri				
43	ExxonMobile	Dock	ExxonMobile	1	1	ExxonMobile				
40	Du Pont & Sun M	Dock	Du Pont & Sun M	2	2	Du Pont & Su				
34	Union Oil	Dock	Union Oil	3	3	Union Oil				
28	Fina Oil	Dock	Fina Oil	4	4	Fina Oil				
20	Lone Star Marine	Dock	Lone Star Marine`	5	5	Lone Star Marine		0	0	0
10	Houston Marine S	Dock	Houston Marine S	6	6	Hou n Marine S		0	0	0
15	Chevron & Motiva	Dock	Chevron & Motiva	7	7	Chevron & Motiva		0	0	0
16		Dock		8	8			0	0	0
4		Dock		9	9			0	0	0
25		Dock		10	10			0	0	0
47	Sun Pipeline Co.	Dock	Sun Pipeline Co	11	11	Sun Pipeline Co		0	0	0

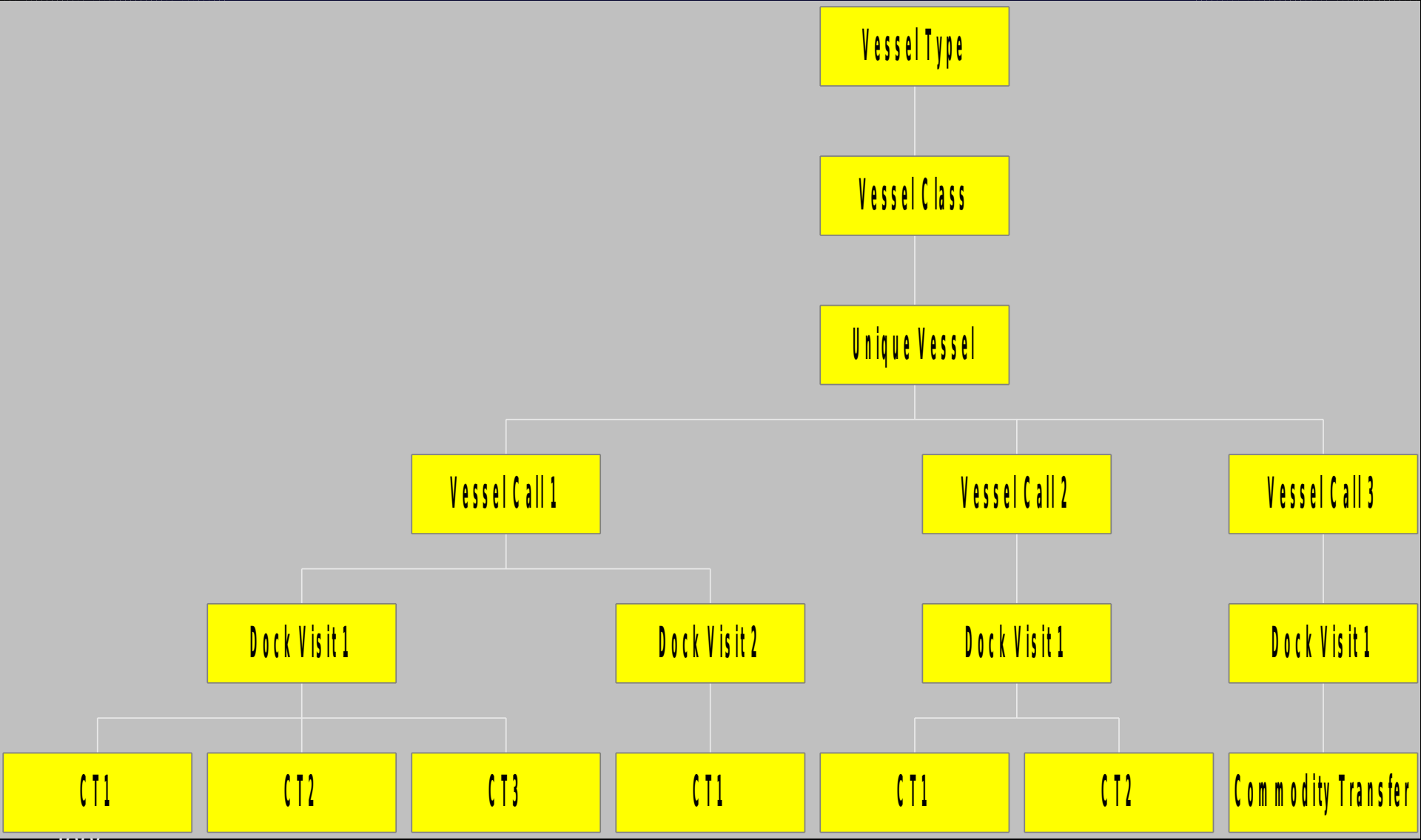
Vessel Call Data Base

- Unique Vessels
  - Vessel class
  - Physical characteristics
- Vessel Call
  - Arrival Time / Draft
- Dock Visits
- Commodity Transfers
  - Quantity / Commodity Category
  - Import/Export

Microsoft Access Relational Data Base

Import From Excel

Vessel Call Database Structure



Cruise Ship - multiple vessel calls

ArrivalDate
1/4/2001 7:00:00 AM
1/8/2001 7:00:00 AM
1/13/2001 6:25:00 AM
1/18/2001 6:25:00 AM
1/22/2001 6:45:00 AM

DockVisitID	DockID	Order	DockArrivalDa	DockDeparture
19	11	1	1/4/2001	
(AutoNumber)		1		

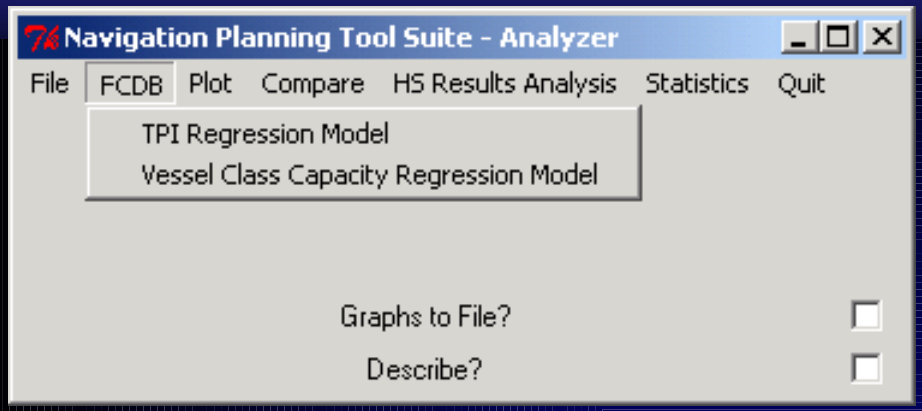
CommodityTra	CommodityTypeID	ExportQuantity	ImportQuantity
23	5	3626	3366
(AutoNumber)			

1/18/2001 6:25:00 AM	1605	1681
1/22/2001 6:45:00 AM	1627	1609
1/27/2001 6:45:00 AM	1619	1629
2/1/2001 12:50:00 PM	1586	1618
2/5/2001 6:45:00 AM	1629	1587
2/10/2001 6:25:00 AM	1666	1626
2/15/2001 5:50:00 AM	1445	1670
2/24/2001 6:00:00 AM	1715	1446
3/1/2001 5:35:00 AM	1586	1716
3/5/2001 5:50:00 AM	1752	1585

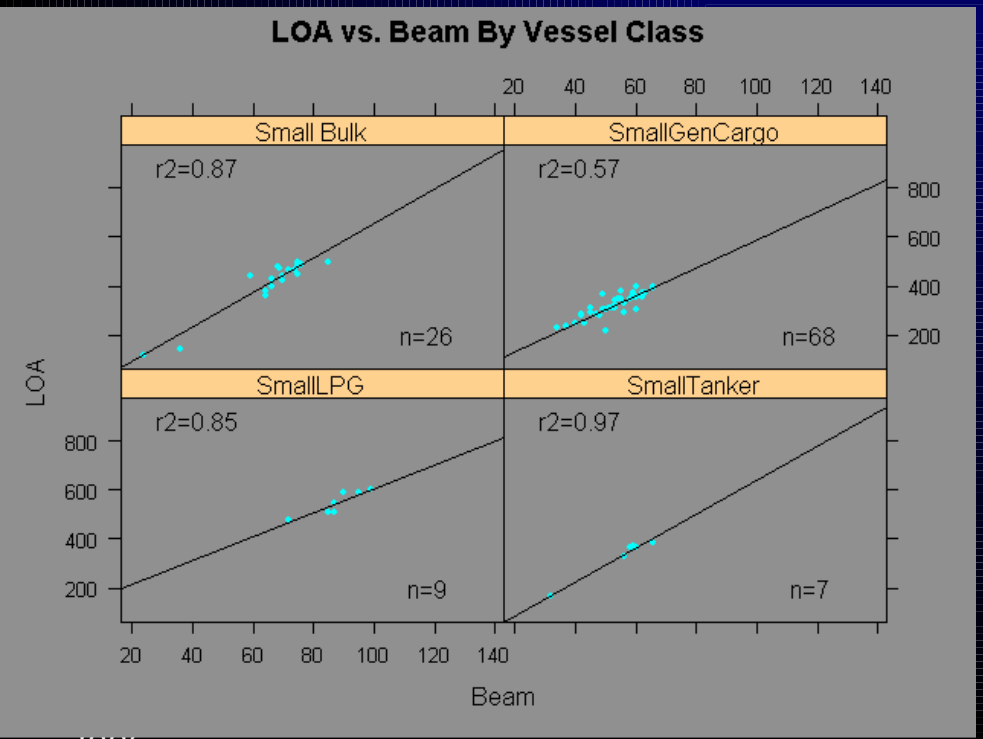
Alternate Views Possible

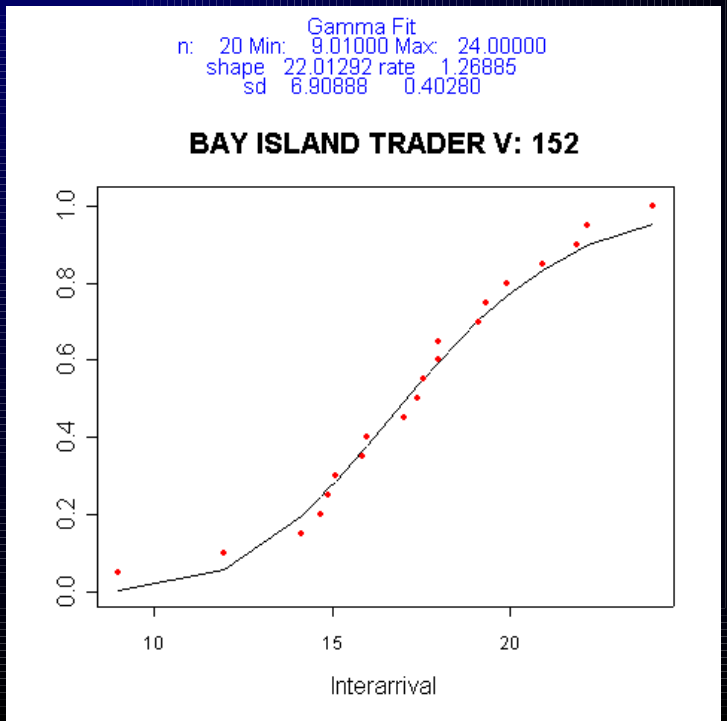
- Vessel Call
  - Time of arrival at port, where vessel goes, commodities transferred
- Vessel
  - Multiple calls of an individual vessel at port
- Dock
  - Stream of commodity transfers over time at each dock
- Commodity Flow
  - Time-based flow of commodities to port
- Fleet
  - Set of Vessels serving port

Vessel Call Analyzer

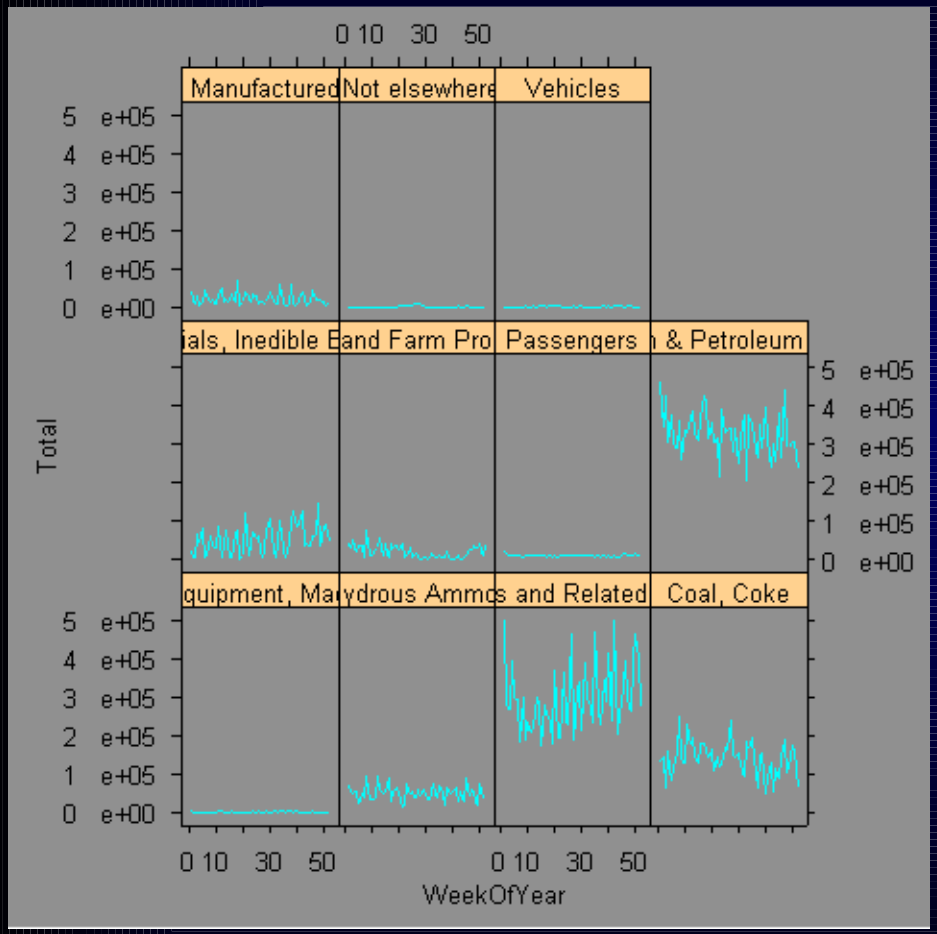


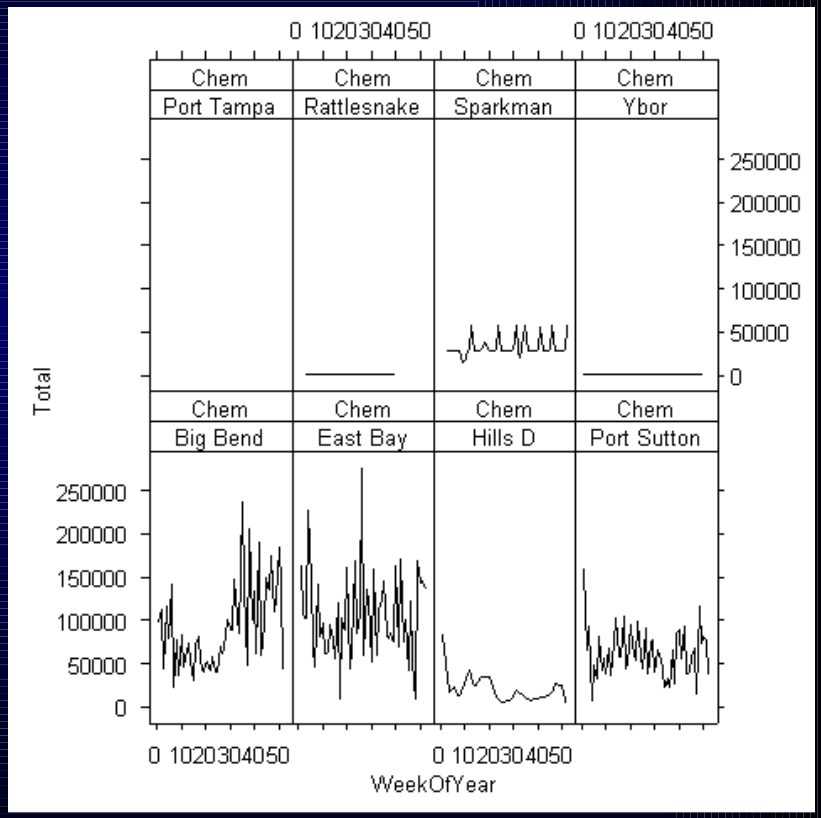
- Examine a Vessel Call Database
- Extract statistics useful for:
  - simulation
  - forecasting
  - generation of synthetic vessel calls





Flow of Commodity To Port / Docks





Commodity-Driven Forecast Tool

- Assist in developing balanced / rational fleet and commodity forecasts
- Develop synthetic vessel calls for HarborSym

- Inputs
  - Commodity / Fleet / Constraints
- Methodology
  - Translate Annual Commodity Forecast to Vessel Calls
  - Use up fleet resource subject to constraints
- Outputs

Inputs

- Commodity Forecast
  - By Dock, Commodity, Import/Export
- Fleet Specification
  - Classes
    - Potential Calls / Priority
    - Statistical Description of Physical Characteristics
  - Loading Factor Distribution By Class/Commodity
- Constraints
    - Dock Draft Limitations
    - Vessel Classes / Commodities
      - What classes carry a commodity

Commodity Forecast At Dock

Commodity Category	Dock	Import Quantity	Export Quantity
Liquid Bulk	StPetersburg	0	8031
Liquid Bulk	Port Manatee	0	133685
Liquid Bulk	Port Tampa	0	143109
Liquid Bulk	Rattlesnake	0	355
Liquid Bulk	Big Bend	0	6956
Liquid Bulk	Port Sutton	0	69621
Liquid Bulk	East Bay	0	69453
Liquid Bulk	Hills Cut D	0	398909
Liquid Bulk	Sparkman	0	169183
Liquid Bulk	Ybor	0	240077
Dry Bulk	Port Manatee	68638	10925
Dry Bulk	Alafia	6831	65583
Dry Bulk	Big Bend	173396	218111
Dry Bulk	Port Sutton	0	317008

Fleet Specification

Vessel Class	Allocation Priority	Maximum Visits
BLKC1	1	55
BLKC2	1	132
BLKC3	1	61
CHEM1	1	118
CHEM2	1	80
CHEM3	1	107
CHEM4	1	1
GCRR1	1	138

Vessel Class	Regression Type	Intercept	Slope
BLKC1	log(Beam)~log(Capacity)	1.719	0.2588
BLKC1	log(LOA)~log(Capacity)	2.7922	0.3490
BLKC1	log(DesignDraft)~log(Capacity)	1.1188	0.2426
BLKC2	log(Beam)~log(Capacity)	1.71354	0.2673
BLKC2	log(LOA)~log(Capacity)	4.4594	0.1852
BLKC2	log(DesignDraft)~log(Capacity)	0.4784	0.2953

Constraints

Dock	Class
Chevron and Motiva	CHEM3
Chevron and Motiva	BLKC1
Chevron and Motiva	GCRR3
Chevron and Motiva	OIL1
Chevron and Motiva	OIL2
Chevron and Motiva	OIL3
Chevron and Motiva	OIL4
DuPont	OIL2
DuPont	OIL4
DuPont	TNKB1
DuPont	OIL3
DuPont and Sun Marine	CHEM2
DuPont and Sun Marine	OIL4
DuPont and Sun Marine	OIL5
DuPont and Sun Marine	TNKB1
DuPont and Sun Marine	TNKB2

Vessel Class	Commodity
BLKC1	Petroleum Products
BLKC1	Grain
BLKC1	Chemicals
BLKC1	Wood
BLKC1	Stone
BLKC1	Iron Ore
BLKC1	Machinery
BLKC2	Petroleum Products
BLKC2	Grain
BLKC2	Chemicals
BLKC2	Wood
BLKC2	Iron Ore
BLKC2	Machi

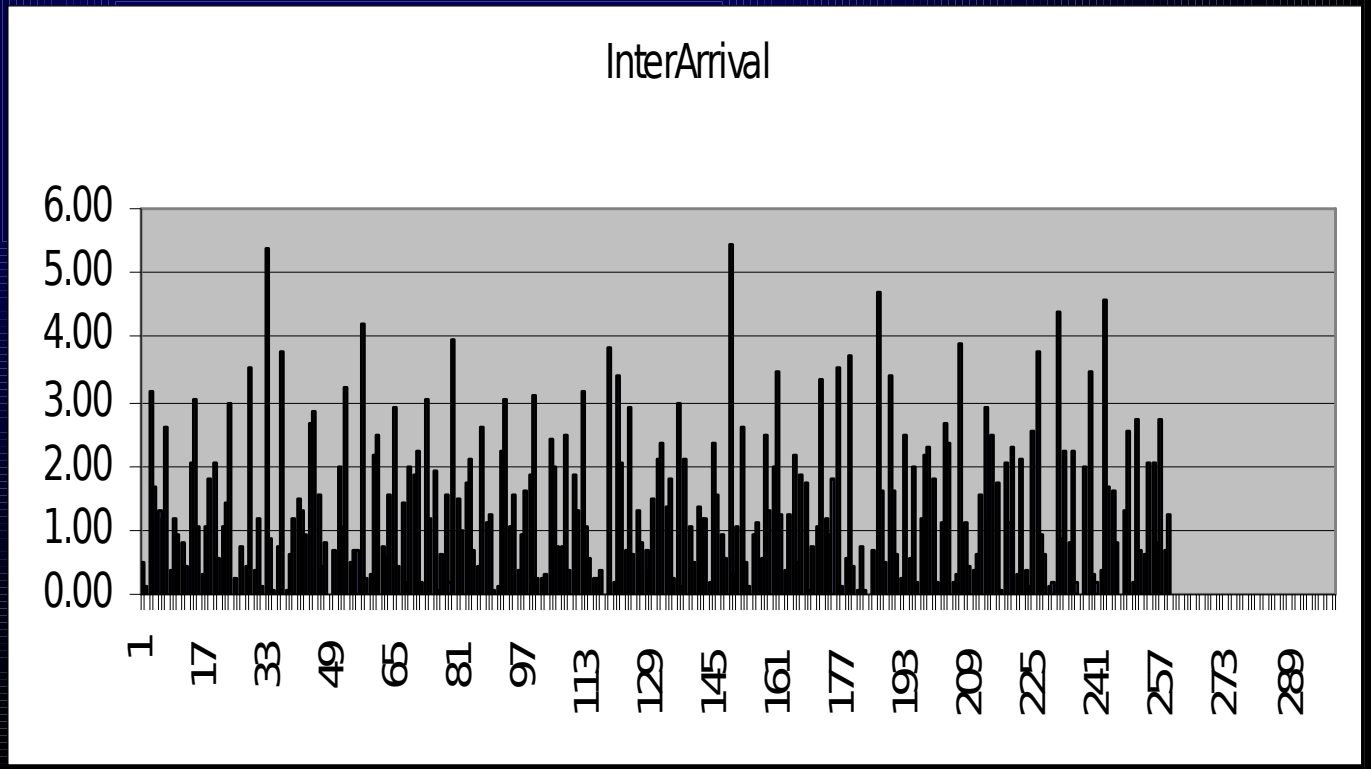
Dock	Limiting Depth
Offshore Marine/LNG	39.5
Houston Marine/LNG	39.5
Chevron and Motiva	39.5
Premcor	39.5

Methodology

- Generate set of distinct vessels based on fleet specification
- Loop through commodity demands
  - Find a vessel that can carry the commodity at the dock (subject to constraints)
  - Load it to maximum, subject to loading factor and depth limitation at dock
  - Reduce commodity demand at dock by amount loaded
  - Remove vessel from available set
  - Next demand
- Stop when:
  - no more suitable vessels available
  - or all forecasts satisfied
- Assign trip times
- Report results / store in database

Outputs

- Logical Consistency
  - Over-constrained?
- Satisfied / Unsatisfied Forecasts
- Fleet Utilization
- Synthetic Vessel Call Data Base

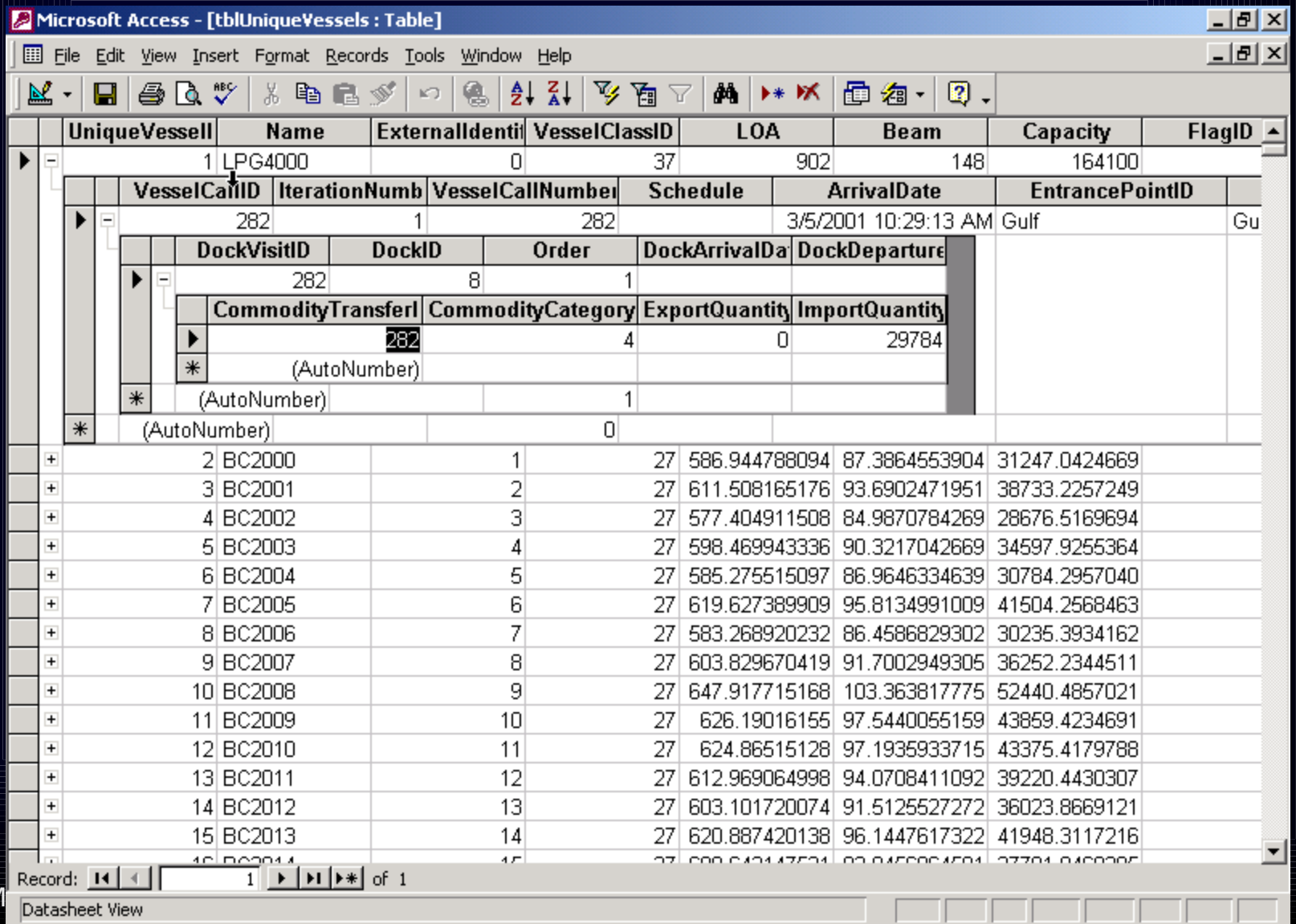


Forecast Tool Outputs - Forecast Satisfaction / Vessel Movements

Commodity	Dock	I/E	Quantity	Allocated	Deficit	% Defict	# Calls
Crude	11 Exxon Mobil	I	2624988 1	7397000	1885288 1	71.82 %	122
Crude	7 Fina Oil	I	2014628 7	7344750	1280153 6	63.54 %	122
Crude	3 Chevron Motiv	I	9072806 2	6332825	2739980	30.20 %	109
Petroleum Products	5 Lone Star	I	69403	69403	0.00	0.00%	2
Petroleum Products	4 Premcor	E	204896	204896	0.00	0.00%	6

Arrival	DockCode	Commodity	Import Quantity	Export Quantity	Entry Draft	Name
1/4/2001 5:33:31 AM	6 DuPont	Crude	66703	0	69.3	OT2000
1/4/2001 1:07:14 PM	8 Union Oil	Crude	90526	0	69.6	OT4006
1/4/2001 6:09:29 PM	3 Chevron Motiv	Crude	38674	0	61.6	OT1000
2/28/2001 11:28:26 AM	8 Union Oil	Petroleum Products	0	28933	18	CT1019
3/5/2001 11:22:00 AM	11 Exxon Mobil	Petroleum Products	0	18162	20	BC1009
3/6/2001 5:37:56 AM	3 Chevron Motiv	Petroleum Products	0	45271	23	GC2009

Output Synthetic Vessel Call Database



Current Simplifying Assumptions

- Each vessel call carries single commodity to/from a single dock
- Each vessel call is either import/export
- Yearly basis (no seasonality)
- No Tide
- Statistical method of generating vessel characteristics
- Assume vessels exporting from port arrive at minimum draft
- Constant inter-arrival time for a class of vessels

Summary

- Suite of tools to assist planners in studies of harbor improvements
  - Data-Driven
  - Transparent
  - Non-Proprietary
- Status
  - HarborSym - available, beta test, used in projects
  - Vessel Analyzer - late stage development
  - Forecast Module - in testing
- For more information:
  - Keith Hofseth, nets@usace.army.mil